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Biology 20–30

Program Outcomes

Resource Development Draft

June 2005

Note: The philosophy and rationale that relates to these outcomes is in the Secondary Science Revisions Program Introduction. Links to the various frameworks within that document are identified in bold with parentheses () after the program outcomes. Links to the Information and Communication Technology (ICT) Program of Studies are identified in bold with square brackets [].

This resource development draft of the program outcomes was initiated based on information collected during the secondary science needs assessment conducted in 1998. It was developed under the guidance of the Alberta Learning Science Interbranch Team with advice from the Science 10–12 Advisory Committee made up of teachers and education stakeholders from across the province. Additional revisions were made based on responses to a questionnaire and other consultations. Additional ICT links will be identified in the program. First Nations, Métis and Inuit (Aboriginal) perspectives have yet to be infused into the program. Further changes may occur after field testing.



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Biology 20

Biology 20 consists of four units of study:

- A. Energy and Matter Exchange in the Biosphere
- B. Ecosystems and Population Change
- C. Photosynthesis and Cellular Respiration
- D. Human Systems

Attitude Outcomes for Biology 20

Students will be encouraged to develop positive attitudes that support the responsible acquisition and application of knowledge related to science and technology. The following attitude outcomes are to be developed throughout the Biology 20 program, in conjunction with the outcomes for Knowledge, Science, Technology and Society (STS) and Skills in each unit.

Interest in Science

Students will be encouraged to:

show interest in science-related questions and issues, and confidently pursue personal interest and career possibilities within science-related fields, e.g.,

- *recognize the usefulness of being skilled at mathematics and problem solving*
- *appreciate how scientific problem solving and the development of new technologies are related*
- *demonstrate interest in science and technologies not directly related to everyday life*
- *explore where further science- and technology-related studies can be pursued.*

Mutual Respect

Students will be encouraged to:

appreciate that scientific understanding evolves from the interaction of ideas involving people with different backgrounds, e.g.,

- *recognize the contributions of various peoples and cultures in furthering understanding and applications of biology.*

Scientific Inquiry

Students will be encouraged to:

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues, e.g.,

- *critically assess their opinion of the value of the applications of science*
- *appreciate the creativity and perseverance required to develop workable solutions to problems.*

Collaboration

Students will be encouraged to:

work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas, e.g.,

- *accept responsibility for any task that helps the group complete an activity*
- *develop a willingness to try various problem-solving strategies and risk being wrong.*

Stewardship

Students will be encouraged to:

demonstrate sensitivity and responsibility in pursuing a balance between the needs of humans and a sustainable environment, e.g.,

- *develop an awareness that the application of technology has risks and benefits*
- *value the contributions of technological innovations in medicine to quality of life*
- *value efforts of parks and specific organizations to preserve habitat for local flora and fauna.*

Safety

Students will be encouraged to:

show concern for safety in planning, carrying out and reviewing activities, e.g.,

- *consider safety a positive limiting factor in scientific and technological endeavours*
- *keep the workstation uncluttered, with only appropriate laboratory materials present.*

Unit A: Energy and Matter Exchange in the Biosphere

Themes: Energy, Equilibrium, Matter and Systems

Unit Overview: The constant flow of energy and cycling of matter in the biosphere leads to a balanced or steady state. This balance is achieved through various biogeochemical cycles and the processes of photosynthesis and cellular respiration.

In this unit, students become familiar with the maintenance of this balance and of how various human activities have impacted the balance.

This unit builds on:

- Science 7, Unit A: Interactions and Ecosystems
- Science 9, Unit A: Biological Diversity
- Science 10, Unit D: Energy Flow in Global Systems

This unit will require approximately 20% of the time allotted for Biology 20.

Links to Mathematics:

The following mathematics topics are not considered as prerequisites.

Topics:	These topics may be found in the following courses:
• plotting nonlinear data	Pure Mathematics 10, specific outcome 3.1; Applied Mathematics 10, specific outcome 3.1
• expressing results of investigations with appropriate recognition of experimental error	Applied Mathematics 20, specific outcomes 6.2, 6.3 and 6.4

Focusing Questions: How are carbon, oxygen, nitrogen and phosphorus cycled in the biosphere? How is the flow of energy balanced in the biosphere? How have human activities and technological advances affected the balance of energy and matter in the biosphere?

General Outcomes: There are three major outcomes in this unit.

Students will:

1. explain the constant flow of energy through the biosphere and ecosystems
2. explain the cycling of matter through the biosphere
3. explain the balance of matter and energy exchange in the biosphere as an open system, and how this maintains equilibrium.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- biosphere
- equilibrium
- trophic levels
- food chains, food webs and pyramids of biomass, energy and numbers
- carbon, nitrogen, oxygen, phosphorus
- water properties

General Outcome 1: *Students will* explain the constant flow of energy through the biosphere and ecosystems.

Outcomes for Knowledge

Students will:

- 20–A1.1k explain, in general terms, the one-way flow of energy through the biosphere and how stored biological energy in the biosphere, as a system, is eventually lost as heat, e.g.,
- *photosynthesis/chemosynthesis*
 - *cellular respiration (muscle-heat generation, decomposition)*
 - *energy transfer by conduction, radiation and convection*
- 20–A1.2k explain how biological energy in the biosphere can be perceived as a balance between both photosynthetic and chemosynthetic, and cellular respiratory activities, i.e.,
- *energy flow in photosynthetic environments*
 - *energy flow in deep sea vent (chemosynthetic) ecosystems and other extreme environments*
- 20–A1.3k explain the structure of ecosystem trophic levels, using models such as food chains and food webs
- 20–A1.4k explain, quantitatively, the energy and matter exchange in aquatic and terrestrial ecosystems, using models such as pyramids of energy, biomass and numbers.

Outcomes for Science, Technology and Society (Emphasis on the nature of science)

Students will:

- 20–A1.1sts explain that the process of scientific investigation includes analyzing evidence and providing explanations based upon scientific theories and concepts by (NS5e)
- *evaluating the evidence for the influence of ice and snow on the trapping of solar energy (albedo effect), and hypothesize on the consequences of fluctuations for biological systems*
 - *explaining how metabolic heat release from harvested grain can be reduced by drying processes prior to grain storage, and explain the scientific principles involved in this technology*
 - *explaining, in terms of energy flow, the advantage of vegetarianism in densely populated countries.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: *Students will explain the constant flow of energy through the biosphere and ecosystems.*

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- Students will:*
- 20–A1.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- *proposing a relationship between producers and available biological energy of a system (IP–STS1)*
 - *predicting a relationship between solar energy storage by plants and varying light conditions (IP–NS3) [ICT C6–4.1].*

Performing and Recording

- Students will:*
- 20–A1.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- *performing an experiment to demonstrate solar energy storage by plants (PR–NS1, 2, 3, 4, 5)*
 - *drawing annotated diagrams, by hand or using technology, of food chains, food webs and ecological pyramids (PR–NS4) [ICT P3–4.1, C6–4.2, P4–4.3].*

Analyzing and Interpreting

- Students will:*
- 20–A1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- *analyzing data on the diversity of plants, animals and decomposers of an endangered ecosystem and predict a future outcome, e.g., *wetlands, short grass prairie* (AI–STS1, 2, 3, 4) [ICT C6–4.1, 4.4]*
 - *describing alternative ways of presenting energy flow data for ecosystems: pyramids of energy, biomass or numbers (AI–STS1) (AI–NS4, 5, 6) [ICT C6–4.2, 4.3]*
 - *analyzing data on the solar energy storage by plants (AI–NS2, 3, 4, 5, 6).*

Communication and Teamwork

- Students will:*
- 20–A1.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *using appropriate SI notation, fundamental and derived units in the data presented in a food pyramid (CT–ST2)*
 - *working cooperatively as a team to investigate, synthesize and present information collected on organism diversity of an endangered ecosystem (CT–STS1, 2, 3, 4) [ICT P6–4.1].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will* explain the cycling of matter through the biosphere.

Outcomes for Knowledge

Students will:

- 20–A2.1k explain and summarize the biogeochemical cycling of carbon, oxygen, nitrogen and phosphorus, and relate this to general reuse of all matter in the biosphere
- 20–A2.2k explain water's primary role in the biogeochemical cycles, using its chemical and physical properties, i.e., universal solvent, hydrogen bonding.

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 20–A2.1sts explain that science and technology have both intended and unintended consequences for humans and the environment by (STS3)
- *discussing the influence of human activities on the biogeochemical cycling of phosphorus, sulphur, iron and nitrogen, e.g.,*
 - *feedlot operations*
 - *composting*
 - *fertilizer applications*
 - *waste and sewage disposal*
 - *vehicular and refinery emissions*
 - *acid deposition*
 - *persistent organic pollutants*
 - *discussing the use of water by society, the impact such use has on water quality and quantity in ecosystems, and the need for water purification and conservation, e.g.,*
 - *manufacturing and processing*
 - *oil industry*
 - *agricultural systems*
 - *mining industry*
 - *domestic daily water consumption*
 - *analyzing the relationship between heavy metals released into the environment and matter exchange in natural food chains/webs, and the impact of this relationship on the quality of life.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will explain the cycling of matter through the biosphere.*

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- Students will:*
- 20–A2.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- designing an experiment to compare the carbon dioxide production of plants with that of animals (IP–NS1, 2, 3, 4, 5) [ICT C7–4.1]
 - hypothesizing how alterations in the carbon cycle as a result of the burning of fossil fuels might interact with other cycling phenomena, e.g., sulphur, iron, water (IP–NS3) [ICT C6–4.1]
 - predicting disruptions in the nitrogen and phosphorus cycles that are caused by human activities (IP–NS3) [ICT C6–4.1].

Performing and Recording

- Students will:*
- 20–A2.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- measuring and recording the pH and the amount of nitrates, phosphates, iron or sulfites in water samples within the local area (PR–NS2, 3, 4) (PR–STS 1) [ICT P2–4.1].

Analyzing and Interpreting

- Students will:*
- 20–A2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- analyzing data collected on water consumption and loss in plants and animals (AI–NS2, 3, 4) [ICT C7–4.2].

Communication and Teamwork

- Students will:*
- 20–A2.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively in a group to investigate the influence of human activities on the biogeochemical cycles and, using appropriate multimedia, presenting the information to a group (CT–STS1, 2, 3, 4) [ICT C1–4.1, P6–4.1].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3: *Students will* explain the balance of energy and matter exchange in the biosphere, as an open system, and how this maintains equilibrium.

Outcomes for Knowledge

- Students will:*
- 20–A3.1k explain the interrelationship of energy, matter and ecosystem productivity (biomass production), e.g.,
- *Antarctic ocean versus tropical seas*
 - *tropical rainforest versus desert*
 - *taiga versus tundra*
 - *intertidal zone versus deep-sea benthos*
 - *Arctic versus Antarctic*
- 20–A3.2k explain how the equilibrium between gas exchanges in photosynthesis and cellular respiration influences atmospheric composition
- 20–A3.3k describe the geological evidence (stromatolites) and scientific explanations for change in atmospheric composition, with respect to O₂ and CO₂, from anoxic conditions to the present and the significance to current biosphere equilibrium.

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

- Students will:*
- 20–A3.1sts explain that science and technology are developed to meet societal needs and expand human capabilities by (STS1)
- *evaluating the technology of a closed system in terms of energy and matter, e.g.,*
 - *space stations and spaceships*
 - *Biosphere experiments*
 - *manned exploration of Mars surface*
- 20–A3.2sts explain that science and technology have both intended and unintended consequences for humans and the environment by (STS3)
- *describing how human activities can have a disrupting influence on the balance, in the biosphere, of photosynthetic and cellular respiratory activities, e.g.,*
 - *fossil fuel combustion*
 - *depletion of stratospheric ozone*
 - *forest destruction.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3: *Students will explain the balance of energy and matter exchange in the biosphere, as an open system, and how this maintains equilibrium.*

Skill Outcomes (Focus on decision making)

Initiating and Planning

- Students will:*
- 20–A3.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- predicting the effects of changes in carbon dioxide and oxygen concentration on the atmospheric equilibrium due to a significant reduction of photosynthetic organisms through human activity (IP–NS3) [ICT C6–4.1].

Performing and Recording

- Students will:*
- 20–A3.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- *collecting evidence from various print and electronic sources on how human activities can have a disrupting influence on photosynthetic and cellular respiratory activities (PR–STS1, 2) [ICT C2–4.1].*

Analyzing and Interpreting

- Students will:*
- 20–A3.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- designing and evaluating a model of a closed biological system in equilibrium with respect to carbon dioxide, water and oxygen exchange (PR–ST2) (AI–ST1) [ICT C6–4.2].

Communication and Teamwork

- Students will:*
- 20–A3.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively as a group to investigate, synthesize and present information on the effects of changes to stratospheric ozone levels on society, agriculture, plants and animals (CT–STS1, 2, 3, 4) [ICT C2–4.1, P6–4.1].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit B: Ecosystems and Population Change

Themes: Energy, Matter and Systems

Unit Overview: In this unit, students become familiar with a range of ecosystems by studying their distinctive biotic and abiotic characteristics. Having been introduced to populations as a basic component of ecosystem structure, students complete the unit by examining population change through the process of natural selection.

This unit prepares students for the study of populations and community dynamics in Biology 30.

This unit builds on:

- Science 7, Unit A: Interactions and Ecosystems
- Science 8, Unit E: Freshwater and Saltwater Systems
- Science 9, Unit A: Biological Diversity.

This unit will require approximately 30% of the time allotted for Biology 20.

Links to Mathematics: None

Focusing Questions: What are the major biotic and abiotic characteristics that distinguish aquatic and terrestrial ecosystems? What data would one need to collect in a field study to illustrate the major abiotic characteristics and diversity of organisms? What mechanisms are involved in the change of populations over time?

General Outcomes: There are two major outcomes in this unit.

Students will:

1. explain that the biosphere is composed of ecosystems, each with distinctive biotic and abiotic characteristics
2. explain the mechanisms involved in the change of populations over time.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- | | |
|----------------------------------|------------------------------|
| • ecosystem | • adaptations and variations |
| • niches | • population |
| • biotic/abiotic characteristics | • natural selection |
| • limiting factors | • species |
| • binomial nomenclature | • evidence for evolution |
| • limiting factors | |

General Outcome 1: *Students will* explain that the biosphere is composed of ecosystems, each with distinctive biotic and abiotic characteristics.

Outcomes for Knowledge

- Students will:*
- 20–B1.1k define and explain the interrelationship among species, population, community and ecosystem
- 20–B1.2k explain how a terrestrial and an aquatic ecosystem supports a diversity of organisms through a variety of habitats and niches, e.g.,
- terrestrial: *canopy, sub-canopy, forest floor, soil*
 - aquatic: *littoral, limnetic, profundal and benthic zones*
- 20–B1.3k identify biotic and abiotic characteristics and explain their influence in an aquatic and a terrestrial ecosystem in a local region, e.g.,
- *stream, lake, prairie, boreal forest, vacant lot, sports field*
- 20–B1.4k explain how limiting factors influence organism distribution and range, e.g.,
- *abiotic factors: soil, relative humidity, moisture, ambient temperature, sunlight, nutrients, oxygen*
 - *biotic factors: competitors, predators and parasites*
- 20–B1.5k explain the fundamental principles of taxonomy, i.e., domains, kingdoms and binomial nomenclature.

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

- Students will:*
- 20–B1.1sts explain that science and technology have both intended and unintended consequences for humans and the environment by (STS3)
- *evaluating the impact that human activity has had, or could have, on the biodiversity in an ecosystem and the influence of the needs and interests of society on this practice, e.g.,*
 - *draining of wetlands*
 - *interbasin water transfer*
 - *habitat fragmentation*
 - *land use*
 - *urbanization*
 - *slash-and-burn and clearcutting practices*
 - *monoculturing, e.g., forests, lawns, agriculture*
 - *assessing the environmental consequences of the introduction of new species to established ecosystems and the responsibility of society to protect the environment through science and technology, e.g.,*
 - *tropical fish in Banff Hot Springs, starlings, quack grass, scented chamomile, purple loosestrife*
- 20–B1.2sts explaining that conventions of mathematics, nomenclature and notation provide a basis for organizing and communicating scientific theory, relationships and concepts by (NS6b)
- *researching the historical development of the modern classification system, e.g., the structural and molecular basis.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: *Students will explain that the biosphere is composed of ecosystems, each with distinctive biotic and abiotic characteristics.*

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- Students will:*
- 20–B1.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues, and define and delimit problems to facilitate investigation by
- hypothesizing the ecological role of biotic and abiotic factors, e.g., *competition and chinooks* (IP–NS3) [ICT C6–4.1] by
 - *planning a field study to gather and evaluate biotic and abiotic characteristics associated with an ecosystem or ecosystems, e.g., effects that dominant plants have on abiotic conditions such as soil and microclimate* (IP–NS1, 2, 3, 4) [ICT C7–4.1].

Performing and Recording

- Students will:*
- 20–B1.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- performing a field study to measure, quantitatively, appropriate abiotic characteristics of an ecosystem or ecosystems and to gather evidence for analysis, both quantitatively and qualitatively, of the diversity of life of the ecosystem(s) studied (PR–NS1, 2, 4, 5)
 - *researching and developing a land reclamation strategy for a disturbed area as a solution to environmental damage, e.g., open-pit mine, garbage dump, school yard reclamation* (PR–STS1) (PR–NS1, 4) [ICT C5–4.1, C1–4.1].

Analyzing and Interpreting

- Students will:*
- 20–B1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- applying classification and binomial nomenclature systems in a field study (AI–NS1)
 - analyzing the interrelationship of biotic and abiotic characteristics that make up the ecosystem(s) studied in the field (AI–NS2, 3, 5, 6)
 - evaluating the accuracy and reliability of instruments used for measurement and identifying the degree of error in the field study data (AI–NS4)
 - *compiling and organizing evidence from a variety of sources, for or against human activity being responsible for ecosystem change and analyzing the relationship between human activity and changing ecosystems* (AI–NS2, 6) (AI–STS2) [ICT C2–4.1].

Communication and Teamwork

- Students will:*
- 20–B1.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively to gather and share data on field trip* (CT–NS1, 2) [ICT P2–4.1, P4–4.3]
 - *working cooperatively to make clear and logical arguments to defend a decision on a given issue, e.g., human impact, land reclamation, wildlife habitat preservation* (CT–STS1, 2, 3, 4) [ICT C7–4.1, 4.3]
 - *developing, presenting and defending a strategy to improve wildlife habitats* (CT–STS3) [ICT C7–4.1, 4.2, 4.3].

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will explain the mechanisms involved in the change of populations over time.*

Outcomes for Knowledge

Students will:

- 20–B2.1k explain that variability in a species results from heritable mutations and that some mutations may have selective advantage(s)
- 20–B2.2k discuss the significance of sexual reproduction to individual variation in populations and to the process of evolution
- 20–B2.3k compare Lamarckian and Darwinian explanations of evolutionary change
- 20–B2.4k summarize and describe lines of evidence to support the evolution of modern species from ancestral forms, i.e., fossil record, Earth's history, embryology, biogeography, homologous and analogous structures, biochemistry
- 20–B2.5k explain speciation and the conditions required for this process
- 20–B2.6k describe modern evolutionary theories, i.e., punctuated equilibrium versus gradualism.

Outcomes for Science, Technology and Society (Emphasis on the nature of science)

Students will:

- 20–B2.1sts explain that scientific knowledge and theories develop through hypotheses, the collection of evidence through experimentation, observation and the ability to provide explanations by (NS2)
 - *discussing the nature of science as a way of knowing, e.g.,*
 - *contributions of Georges Buffon, Charles Lyell, Thomas Malthus and Alfred Russel Wallace to evolution*
 - *contributions of Aristotle, Bacon and Popper to the philosophy of science*
 - *describing how paleontology and the role of evidence in the accumulation of knowledge has provided invaluable data for theories explaining observable variations in organisms over time, e.g., Burgess Shale*
 - *discussing probable causes and geological evidence for past mass extinctions and contrast these to the forces driving the current decline in species.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will* explain the mechanisms involved in the change of populations over time.

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- Students will:*
- 20–B2.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- designing an investigation to measure or describe an inherited variation in a plant or animal population (IP–NS1, 2, 3, 4) [ICT C7–4.1]
 - hypothesizing the adaptive significance of the variations in a range of homologous structures in extant and extinct organisms (IP–NS3) [ICT C6–4.1].

Performing and Recording

- Students will:*
- 20–B2.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- *gathering data, actual or simulated, on organisms to demonstrate how inherited characteristics change over time, e.g., Darwin's finches, peppered moth, bacteria, domesticated plants and animals (PR–NS1, 4) [ICT C1–4.1].*

Analyzing and Interpreting

- Students will:*
- 20–B2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- analyzing data, actual or simulated, on plants and animals to demonstrate how morphology changes over time, e.g., *Darwin's finches, peppered moth, bacteria, domesticated plants or animals (AI–NS2) [ICT C6–4.4, C1–4.1]*
 - *analyzing DNA sequences from online or other sources to infer the relationship between kingdoms, phyla, species and varieties, e.g., grapes, dogs (AI–NS2) [ICT C1–4.1]*
 - *stating a conclusion or generalization based on research data, explaining how it supports or refutes biological change, and identifying new questions or problems that arise from what was learned (AI–NS5, 6) [ICT C7–4.2].*

Communication and Teamwork

- Students will:*
- 20–B2.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *using appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results (CT–NS1, 2) [ICT P2–4.1].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit C: Photosynthesis and Cellular Respiration

Themes: Energy, Matter and Systems

Unit Overview: The life processes of photosynthesis and cellular respiration allow for the transfer of energy and matter. Students learn, in general terms, of how energy from sunlight is transferred into the products of adenosine triphosphate (ATP) and reduced nicotinamide adenine dinucleotide phosphate (NADPH) and eventually into glucose, and how carbohydrates are oxidized to produce NADPH, reduced flavin adenine dinucleotide (FADH) and eventually ATP. A detailed knowledge of metabolic intermediates is not required.

Students extend their understanding by examining how these cellular processes impact and are impacted by global systems.

This unit builds upon:

- Science 7, Unit B: Food and Fibre
- Science 10, Unit C: Flow of Matter in Living Systems

This unit will require approximately 10% of the time allotted for Biology 20.

Links to Mathematics: None

Focusing Questions: How does light energy from the environment enter living systems? How is the energy from light used to synthesize organic matter? How is the energy in organic matter released for use by living systems?

General Outcomes: There are two major outcomes in this unit.

Students will:

1. relate photosynthesis to storage of energy in compounds
2. explain the role of cellular respiration in releasing potential energy from organic compounds.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- absorption of light by pigments
- light-dependent and independent reactions
- glycolysis
- Krebs cycle and electron transport systems
- comparison of aerobic and anaerobic respiration

General Outcome 1: *Students will* relate photosynthesis to storage of energy in organic compounds.

Outcomes for Knowledge

Students will:

- 20–C1.1k explain, in general terms, how pigments absorb light and transfer that energy as reducing power in nicotinamide adenine dinucleotide phosphate (NADP), reduced nicotinamide adenine dinucleotide phosphate (NADPH) and finally into chemical potential in adenosine triphosphate (ATP) by chemiosmosis, describing where those processes occur in the chloroplast
- 20–C1.2k explain, in general terms, how the products of the light-dependent reactions, NADPH and ATP, are used to reduce carbon in the light-independent reactions for the production of glucose, describing where the process occurs in the chloroplast.
- Note:** Detailed knowledge of metabolic intermediates is not required.

Outcomes for Science, Technology and Society (Emphasis on science and technology)

Students will:

- 20–C1.1sts explain how scientific knowledge may lead to the development of new technologies and new technologies may lead to scientific discovery by (ST4)
- *analyzing the role of photosynthesis as the biological basis of agriculture and forestry*
- 20–C1.2sts explain that the appropriateness, risks and benefits of technologies need to be assessed for each potential application from a variety of perspectives, including sustainability by (ST7)
- *researching and analyzing the effects of herbicides on the biochemistry of photosynthesis.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: *Students will* relate photosynthesis to storage of energy in organic compounds.

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- 20–C1.1s *Students will:*
ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- *identifying a testable factor that would affect the rate of photosynthesis (IP–NS1)*
 - *predicting and hypothesizing the effect of changes in carbon dioxide and oxygen concentration on photosynthesis (IP–NS3) [ICT C6–4.1].*

Performing and Recording

- 20–C1.2s *Students will:*
conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- *measuring rates of evapotranspiration under various environmental conditions and relate to photosynthetic activity (PR–NS1, 2, 3, 4)*
 - *investigating and integrating, from print and electronic sources, information on the C₃ and C₄ photosynthetic mechanisms and applications of cellular biochemistry in medicine or industry (PR–NS1, 4) [ICT C1–4.1, 4.3].*

Analyzing and Interpreting

- 20–C1.3s *Students will:*
analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- *collecting and interpreting data and calculating R_f (reference flow) values from chromatography experiments (PR–NS2) (AI–NS2, 3, 4) [ICT F1–4.2]*
 - *drawing analogies between the storage of energy by photosynthesis and the storage of energy by active solar generating systems (AI–NS4)*
 - *explaining how data supports or refutes the hypothesis on how changes in carbon dioxide and oxygen concentration affect photosynthesis (AI–NS4)*
 - *collecting and interpreting experimental data that demonstrates that plant leaves produce starch in the presence of light (PR–NS2) (AI–NS2).*

Communication and Teamwork

- 20–C1.4s *Students will:*
work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively as a group to investigate, synthesize and present information on the effects of herbicides on the biochemistry of photosynthesis (CT–STS1, 2, 3, 4) [ICT C2–4.1, P6–4.1].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will* explain the role of cellular respiration in releasing energy from organic compounds.

Outcomes for Knowledge

Students will:

- 20–C2.1k explain, in general terms, how carbohydrates are oxidized by glycolysis and Krebs cycle to produce reducing power in NADH and FADH, and chemical potential in ATP, describing where in the cell those processes occur
[Note: Specific detailed knowledge of the metabolic intermediates is not required.]
- 20–C2.2k explain, in general terms, how chemiosmosis converts the reducing power of NADH and FADH to the chemical potential of ATP, describing where in the mitochondria the process occurs
Note: Specific detailed knowledge of the biochemistry of the reactions is not required.
- 20–C2.3k distinguish, in general terms, between animal and plant fermentation and aerobic respiration
- 20–C2.4k summarize and explain the role of ATP in cell metabolism, e.g.,
- *active transport*
 - *cytoplasmic streaming*
 - *phagocytosis*
 - *biochemical synthesis*
 - *muscle contraction*
 - *heat production.*

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 20–C2.1sts explain that science and technology are developed to meet societal needs and expand human capability by (STS1)
- *researching applications of cellular biochemistry in health and industry; e.g.*
 - *aerobic and anaerobic fitness*
 - *methane gas production from organic waste*
 - *alcohol production*
 - *bread making*
 - *yogurt*
- 20–C2.2sts explain that science and technology have both intended and unintended consequences for humans and the environment by (STS3)
- *discussing how pollutants such as cyanide and hydrogen sulfide have specific metabolic effects on aerobic organisms when released into the environment.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will explain the role of cellular respiration in releasing energy from organic compounds.*

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- Students will:*
- 20–C2.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- *identifying factors affecting the rate of cellular respiration (IP–NS1) [ICT C7–4.1]*
 - *designing an experiment to demonstrate that heat is a byproduct of respiration in autotrophs and heterotrophs (IP–NS1, 2, 3, 4) [ICT C7–4.1]*
 - *predicting and hypothesizing the effect of oxic and anoxic conditions on the rate of cellular respiration in unicellular organism, i.e., yeast, bacteria (IP–NS3) [ICT C6–4.1].*

Performing and Recording

- Students will:*
- 20–C2.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- *using experimental methods to demonstrate, quantitatively, the oxygen consumption of germinating seeds (PR–NS1, 2, 3, 4, 5)*
 - *measuring temperature change over time of germinating and non-germinating seeds (PR–NS1, 2, 3, 4, 5)*
 - *investigating and integrating, from print and electronic sources, information on the action of metabolic toxins, such as hydrogen sulfide and cyanide, on cellular respiration (PR–NS1, 4) [ICT C1–4.1, 4.2].*

Analyzing and Interpreting

- Students will:*
- 20–C2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- *evaluating reliability, accuracy and validity of sources used to collect information on metabolic toxins and cellular respiration (AI–NS4) [ICT C3–4.1, 4.2]*
 - *interpreting data on the oxygen consumption of an animal (AI–NS2, 3, 4, 5, 6)*
 - *explaining how data support or refute the hypothesis that explains the effect of oxic and anoxic conditions on the rate of cellular respiration in unicellular organisms (AI–NS6).*

Communication and Teamwork

- Students will:*
- 20–C2.4s work as members of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively to research and investigate anoxic and oxic cellular respiration and metabolic toxins (CT–STS1, 2, 4) [ICT C1–4.1, 4.2].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit D: Human Systems

Themes: Energy, Equilibrium, Matter and Systems

Unit Overview: Maintenance of metabolic equilibrium in organisms involves a number of physical and biochemical processes. The human organism is used as a model system to examine how energy and matter are exchanged with the environment through the processes of gas exchange, digestion, excretion, circulation and the function of the motor system. A defense system contributes to equilibrium by eliminating pathogenic organisms.

This unit prepares students for further studies of the functioning of human systems.

This unit builds on:

- Science 8, Unit B: Cells and Systems
- Science 10, Unit C: Flow of Matter in Living Systems

This unit will require approximately 40% of the allotted time for Biology 20.

Links to Mathematics: None

Focusing Questions: How do specialized structures function in the overall biochemical balance of the living system? What conditions result if these structures do not function normally?

General Outcomes: There are four major outcomes in this unit.

Students will:

1. explain how the human digestive and respiratory systems exchange energy and matter with the environment
2. explain the role of the circulatory and defense systems in maintaining an internal equilibrium
3. explain the role of the excretory system in maintaining an internal equilibrium in humans through the exchange of energy and matter with the environment
4. explain the role of the motor system in the function of other body systems.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- structure and function of major systems:
 - respiratory, digestive, excretory, circulatory and motor
- chemical nature of carbohydrates, proteins, lipids
- chemical and physical digestion
- digestive enzymes
- gas exchange
- composition of blood
- immune response
- renal function
- muscle contraction

General Outcome 1: *Students will* explain how the human digestive and respiratory systems exchange energy and matter with the environment.

Outcomes for Knowledge

Students will:

- 20–D1.1k identify the principal structures of the digestive and respiratory systems, i.e.,
- mouth, esophagus, stomach, sphincters, small and large intestines, liver, pancreas, gall bladder
 - nasal passages, pharynx, larynx, epiglottis, trachea, bronchi, bronchioles, alveoli, diaphragm, rib muscles, pleural membranes
- 20–D1.2k describe the chemical nature of carbohydrates, fats and proteins and their enzymes, i.e., carbohydrases, proteases and lipases
- 20–D1.3k explain enzyme action and factors influencing their action
- 20–D1.4k describe the chemical and physical processing of matter through the digestive system into the bloodstream
- 20–D1.5k explain how gases and heat are exchanged between the human organism and its environment, i.e., mechanism of breathing, gas exchange, removal of foreign material.

Outcomes for Science, Technology and Society (Emphasis on science and technology)

Students will:

- 20–D1.1sts explain that the goal of technology is to provide solutions to practical problems by (ST1)
- *discussing and evaluating the role of food additives and/or food treatment to solve the problems of food spoilage, e.g., antioxidants, irradiation technology*
 - *explaining the biological basis of nutritional deficiencies, including that of anorexia nervosa, and the technological means available to restore equilibrium of body systems*
 - *identifying specific pathologies of the digestive and respiratory systems and the technology used to treat the conditions*
- 20–D1.2sts explain that the products of technology are devices, systems and processes that meet given needs; however, these products cannot solve all problems by (ST7)
- *assessing the physiological effects of smoking and the limitations of technologies available to deal with these conditions or diseases.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: *Students will* explain how the human digestive and respiratory systems exchange energy and matter with the environment.

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- Students will:*
- 20–D1.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- *designing an investigation to examine food energy through calorimetry (IP–NS1, 2, 3, 4) [ICT C7–4.1]*

Performing and Recording

- Students will:*
- 20–D1.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- observing, through dissection or computer simulations, the respiratory and digestive systems of a representative mammal and identifying the major structural components (PR–NS1, 2, 3, 4, 5) [ICT F1–4.2]
 - performing experiments, using qualitative tests to detect the presence of carbohydrates, proteins and lipids (PR–NS2, 3, 4, 5)
 - *designing and performing an experiment to investigate the influence of enzyme concentration, temperature or pH on activity of enzymes, e.g., pepsin, pancreatin*
 - *designing and performing an experiment to examine the mechanics of breathing, e.g., lung volume, breathing rate.*

Analyzing and Interpreting

- Students will:*
- 20–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- *performing, recording, analyzing, drawing conclusions and assessing validity of data from the investigation on calorimetry, enzyme action and mechanics of breathing (PR–NS1, 2, 3, 4, 5) (AI–NS2, 3, 4, 6) [ICT P2–4.1].*

Communication and Teamwork

- Students will:*
- 20–D1.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively to collect and communicating results using appropriate terminology, SI units and symbols (CT–NS1, 2) [ICT P2–4.1].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed

General Outcome 2: *Students will* explain the role of the circulatory and defense systems in maintaining an internal equilibrium.

Outcomes for Knowledge

Students will:

- 20–D2.1k identify the principal structures of the heart and associated blood vessels, i.e., atria, ventricles, septa, valves, aorta, vena cavae, pulmonary arteries and veins, sinoatrial node
- 20–D2.2k describe the action of the heart and the general circulation of the blood through coronary, pulmonary and systemic pathways
- 20–D2.3k describe the structure and function of blood vessels; i.e., arteries, veins, and capillaries
- 20–D2.4k describe the main components of blood and their role in transport and in resisting the influence of pathogens; i.e., erythrocytes, leucocytes, platelets, plasma
- 20–D2.5k explain the role of the circulatory system at the capillary level in aiding the digestive, excretory, respiratory and motor systems' exchange of energy and matter with the environment
- 20–D2.6k explain the role of blood in regulating body temperature
- 20–D2.7k describe and explain, in general terms, the function of the lymphatic system
- 20–D2.8k list the main cellular and non-cellular components of the human defense system and describe their role, i.e., skin, macrophage, helper T cell, B cell, killer T cell, suppressor T cell, memory T cell.

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 20–D2.1sts explain how Canadian society supports scientific research and technological development that helps achieve a sustainable society, economy and environment by (STS4a)
 - *evaluating the effects that the needs, interests and financial support of society have on preventing the spread of disease-causing organisms, e.g., Staphylococcus, smallpox virus, E. coli and the human immunodeficiency virus (HIV)*
 - *identifying specific pathologies of the circulatory and defense systems, the technology used to treat the conditions and the reasons society supports the development of such technologies*
 - *assessing the physiological effect of drugs such as alcohol and nicotine on the circulatory system and why habitual use of these drugs is a societal concern*
- 20–D2.2sts explain that decisions regarding the application of scientific and technological developments involve a variety of perspectives, including social, cultural, environmental, ethical and economic considerations by (STS4b)
 - *evaluating the ethical implications of organ transplants in terms of the needs, interests and financial support of society on scientific and technological research in this field, e.g., societal and scientific definitions of death*
 - *analyzing the considerations associated with technological advances that assist in the maintenance of internal equilibrium with respect to:*
 - *pathogens, e.g., vaccinations/inoculations*
 - *defective hearts, e.g., artificial valves, artificial hearts, xenotransplantation, stem cell culture*
 - *delivery of prescription drugs to sites of action.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will explain the role of the circulatory and defense systems in maintaining an internal equilibrium.*

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- 20–D2.1s *Students will:*
ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- *designing procedures to investigate factors affecting heart rate and blood pressure, e.g., physical activity, emotion, gender and chemicals such as caffeine (IP–NS4) [ICT C7–4.1].*

Performing and Recording

- 20–D2.2s *Students will:*
conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- *measuring blood pressure and observing blood flow in capillaries in a living organism or through demonstration in a virtual lab, e.g., human, goldfish (PR–NS2, 3)*
 - *determining the morphology and abundance of cellular components in a prepared human blood slide (PR–NS2, 3)*
 - *selecting and integrating information from various sources to observe the principal features of a mammalian circulatory system and the direction of blood flow and identifying structures from drawings, e.g., valves, chambers. (PR–NS1) [ICT C1–4.1]*
 - *researching and designing a simulation or model of the functioning of the main components of the human immune system (PR–NS1) (PR–ST2) [ICT C6–4.2]*
 - *compiling and displaying information on blood pressure, heart rate and blood composition and researching statistical data (PR–NS1, 4) [ICT P4–4.3]*
 - *carrying out a heart dissection to identify the major parts and to determine the directional flow of blood through the organ (IP–NS4).*

Analyzing and Interpreting

- 20–D2.3s *Students will:*
analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- *determining the relationship between blood pressure and exercise from patterns and trends in data (AI–NS2) [ICT C6–4.3]*
 - *investigating lifestyle behaviour, physical fitness and heart rate recovery using statistical theoretical data and account for discrepancies (AI–NS2, 3) [ICT C7–4.1, 4.2]*
 - *identifying the limitations and evaluate the dependability of devices used to measure blood pressure (AI–NS 4)*
 - *analyzing the heart-lung machine (AI–ST2) [ICT C7–4.1, 4.2]*
 - *exploring solutions to practical problems associated with the circulatory system, e.g., heart transplant, artificial blood, blood doping to enhance athletic performance (AI–ST2) [ICT C1–4.1, 4.2].*

Communication and Teamwork

- 20–D2.4s *Students will:*
work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively with team members to measure and record blood pressure, heart rate or any other factor relating to the circulatory system (CT–NS1, 2) [ICT P4–4.3].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3: *Students will* explain the role of the excretory system in maintaining an internal equilibrium in humans through the exchange of energy and matter with the environment.

Outcomes for Knowledge

Students will:

- 20–D3.1k identify the principal structures of the excretory system, i.e., kidneys, ureters, urinary bladder, urethra
- 20–D3.2k explain the structure and function of the nephron in maintaining normal body fluid composition, i.e., water, pH, ions
- 20–D3.3k describe the function of the kidney in excreting metabolic wastes and expelling them into the environment.

Outcomes for Science, Technology and Society (Emphasis on the nature of science)

Students will:

- 20–D3.1sts explain that the goal of science is knowledge about the natural world by (NS1)
 - *examining how lifestyle factors contribute to hypertension and affect kidney function, e.g.,*
 - *drugs such as alcohol and nicotine*
 - *sedentary lifestyle*
 - *dietary excesses or deficiencies*
 - *stress*
 - *explaining how our understanding of nephron function is applied to renal and peritoneal dialysis*
 - *identifying specific pathologies of the excretory system and the scientific knowledge connected with the treatment*
 - *identifying the physiological complexities and challenges of organ transplant.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3: *Students will explain the role of the excretory system in maintaining an internal equilibrium in humans through the exchange of energy and matter with the environment.*

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- Students will:*
- 20–D3.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- *predicting how blood pressure affects urine formation, composition and volume (IP–NS1) [ICT C6–4.1].*

Performing and Recording

- Students will:*
- 20–D3.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- researching and creating a flow chart to describe how humans maintain homeostasis with respect to water and ions, e.g., (PR–NS1) [ICT C7–4.1, 4.2]
 - *water uptake is high, e.g., tea, carbonated soft drink*
 - *action of diuretic compounds, e.g., caffeine, ethanol*
 - *sodium intake is excessive, e.g., anchovy pizza*
 - *performing a kidney dissection to identify major parts of the organ (IP–NS4).*

Analyzing and Interpreting

- Students will:*
- 20–D3.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- observing the principal features of a mammalian excretory system and identifying structures from drawings obtained from various print and electronic sources (AI–NS1) [ICT C1–4.1]
 - collecting and interpreting data in analysis of simulated urine, identifying limitations of data, comparing to theoretical values, and producing a generalization (PR–NS1, 2, 3, 4, 5) (AI–NS2, 4, 6) [ICT C6–4.4]
 - making analogies between kidney function and renal and peritoneal dialysis (AI–ST2); and, e.g. by
 - *assessing technological solutions to kidney failure, e.g., peritoneal dialysis, hemodialysis and kidney transplant and identifying the potential strengths and weaknesses of each (AI–ST2) [ICT C2–4.1, 4.2].*

Communication and Teamwork

- Students will:*
- 20–D3.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively with team members to assess and record simulated urine composition (CT–NS1, 2) [ICT C6–4.3, C7–4.2].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 4: *Students will* explain the role of the motor system in the function of other body systems.

Outcomes for Knowledge

Students will:

- 20–D4.1k explain how the motor system supports body functions, i.e., circulatory, respiratory, digestive, excretory and locomotory
- 20–D4.2k describe, in general, the action of actin and myosin in muscle contraction and heat production.

Outcomes for Science, Technology and Society (Emphasis on the nature of science)

Students will:

- 20–D4.1sts explain that concepts, models and theories are often used in interpreting and explaining observations, and in predicting future observations by (NS6a)
- *analyzing the effects of exercise on the muscle fiber*
 - *describing the relationship between fitness and efficiency of muscle action*
 - *assessing the physiological effects on the motor system of drugs such as steroids, creatine phosphate, energy-enhancing drugs*
- 20–D4.2sts explain that the goal of technology is to provide solutions to practical problems by (ST1)
- *identifying specific pathologies of the motor system and the technology used to treat the conditions.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 4: *Students will explain the role of the motor system in the function of other body systems.*

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- Students will:*
- 20–D4.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- *designing an investigation to determine the relationship between muscle activity and energy (IP–NS1, 2, 3, 4) [ICT C7–4.1].*

Performing and Recording

- Students will:*
- 20–D4.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- observing types of muscle under magnification (PR–NS3)
 - *designing and constructing a model of a muscle fiber (PR–ST2), [ICT C7–4.1].*

Analyzing and Interpreting

- Students will:*
- 20–D4.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- *obtaining and interpreting data to demonstrate a direct correlation between energy use by muscle cells and heat production (PR–NS1, 2, 3, 4) (AI–NS2)*
 - *evaluating dependability of technologies used for temperature measurement, assessment or analysis and identifying limitations of such measurements (AI–NS3, 4).*

Communication and Teamwork

- Students will:*
- 20–D4.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively with team members to measure body temperature (CT–NS1)*
 - *using appropriate SI notation, fundamental and derived units (CT–NS2).*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Biology 30

Biology 30 consists of four units of study:

- A. Nervous and Endocrine Systems
- B. Reproduction and Development
- C. Cell Division, Genetics and Molecular Biology
- D. Population and Community Dynamics

Attitude Outcomes for Biology 30

Students will be encouraged to develop positive attitudes that support the responsible acquisition and application of knowledge related to science and technology. The following attitude outcomes are to be developed throughout the Biology 30 program, in conjunction with the outcomes for Knowledge, Science, Technology and Society (STS) and Skills in each unit.

Interest in Science

Students will be encouraged to:

show interest in science-related questions and issues, and confidently pursue personal interest and career possibilities within science-related fields, e.g.,

- *recognize the usefulness of being skilled at mathematics and problem solving*
- *appreciate how scientific problem solving and the development of new technologies are related*
- *demonstrate interest in science and technologies not directly related to everyday life*
- *explore where further science- and technology-related studies can be pursued.*

Mutual Respect

Students will be encouraged to:

appreciate that scientific understanding evolves from the interaction of ideas involving people with different backgrounds, e.g.,

- *recognize the contributions of various peoples and cultures in furthering understanding and applications of biology.*

Scientific Inquiry

Students will be encouraged to:

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues, e.g.,

- *critically assess their opinion of the value of the applications of science*
- *appreciate the creativity and perseverance required to develop workable solutions to problems.*

Collaboration

Students will be encouraged to:

work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas, e.g.,

- *accept responsibility for any task that helps the group complete an activity*
- *develop a willingness to try various problem-solving strategies and risk being wrong.*

Stewardship

Students will be encouraged to:

demonstrate sensitivity and responsibility in pursuing a balance between the needs of humans and a sustainable environment, e.g.,

- *develop an awareness that the application of technology has risks and benefits*
- *value the contributions of technological innovations in medicine to quality of life.*

Safety

Students will be encouraged to:

show concern for safety in planning, carrying out and reviewing activities, e.g.,

- *consider safety a positive limiting factor in scientific and technological endeavours*
- *keep the workstation uncluttered, with only appropriate laboratory materials present.*

Unit A: Nervous and Endocrine Systems

Themes: Equilibrium and Systems

Overview: This unit examines the biological processes that mediate the interactions between humans and their environment to maintain equilibrium. The nervous system contributes to homeostasis through its response to internal and external stimuli. Endocrine glands help to maintain homeostasis through the hormones they release into the blood. A study of the interactions between the nervous and endocrine systems leads to an examination of the functioning of the central and peripheral nervous systems and their ability to sense the environment and respond to it.

This unit builds on:

- Science 8, Unit B: Cells and Systems
- Science 10, Unit C: Flow of Matter in Living Systems
- Biology 20, Unit D: Human Systems

This unit will require approximately 25% of the time allotted for Biology 30.

Links to Mathematics: None

Focusing Questions: How does the human body maintain equilibrium between its internal and external environments? What physiological processes and control systems are involved in maintaining homeostasis?

General Outcomes: There are two major outcomes in this unit.

Students will:

1. explain how the nervous system controls physiological processes
2. explain how the endocrine system contributes to homeostasis.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- neuron
- nerve impulse transmission
- central and peripheral nervous systems
- reflex arc
- sensory receptors
- endocrine system and hormones
- homeostasis and feedback systems
- endocrine and nervous system interactions

General Outcome 1: *Students will explain how the nervous system controls physiological processes.*

Outcomes for Knowledge

Students will:

- 30–A1.1k describe the structure and function of a neuron and myelin sheath, explaining the formation and transmission of an action potential and the transmission of a signal across a synapse or neuromuscular junction and the main chemicals and transmitters involved, i.e., norepinephrine, acetylcholine and cholinesterase
- 30–A1.2k identify the principal structures of the central and peripheral nervous systems and explain their functions in regulating the voluntary (somatic) and involuntary (autonomic) systems of the human organism, i.e., cerebral hemispheres and lobes, cerebellum, pons, medulla oblongata, hypothalamus, spinal cord, sympathetic and parasympathetic nervous systems, and the sensory-somatic nervous system
- 30–A1.3k describe the composition and function of a simple reflex arc and the organization of neurons into nerves
- 30–A1.4k describe the structure and function of the human eye, i.e., cornea, lens, sclera, choroid, retina, rods and cones, pupil, iris, and optic nerve
- 30–A1.5k describe the structure and function of the human ear, i.e., pinna, auditory canal, tympanum, ossicles, cochlea, organ of Corti, auditory nerve, semicircular canals and Eustachian tube
- 30–A1.6k explain other ways that human organisms sense their environment and their spatial orientation in it, e.g., *skin receptors, olfactory receptors, proprioceptors, taste receptors.*

Outcomes for Science, Technology and Society (Emphasis on the nature of science)

Students will:

- 30–A1.1sts explain that scientific knowledge and theories develop through hypotheses, collection of evidence through experimentation and the ability to provide explanations by (NS2)
 - *discussing the biological basis of neurological diseases and how this relates to its treatment, e.g., Alzheimer's disease, Parkinson's disease*
 - *evaluating the impact of photoperiod (light wavelength and duration) on the human organism*
- 30–A1.2sts explain that scientific investigation includes the process of analyzing evidence and providing explanations based on scientific theories and concepts by (NS5e)
 - *analyzing experimental evidence on the influence of anesthetics, drugs and chemicals, natural and synthetic, on the functioning of the nervous system and their relationship to addiction theories*
 - *analyzing the contribution of technological developments and physiological knowledge to longevity and quality of life*
- 30–A1.3sts explain that the goal of technology is to provide solutions to practical problems by (ST1)
 - *investigating the technologies available to correct eye and ear defects*
 - *investigating the biological basis of neurotoxin action and their antidotes, e.g., snake venom, box jellyfish, botulin, reserpine (Rauwolfia serpentina)*
 - *discussing how advances in science have contributed to technologies that increase access to the world beyond normal sensory limits.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: *Students will explain how the nervous system controls physiological processes.*

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- 30–A1.1s *Students will:*
ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues by
- designing an experiment to investigate heat, cold, pressure and touch receptors (IP–NS1, 2, 3) [ICT C7–4.1].

Performing and Recording

- 30–A1.2s *Students will:*
conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- designing and performing an experiment to investigate the physiology of reflex arcs (IP–NS1, 2, 3) (PR–NS1, 2, 3, 4) [ICT C7–4.1]
 - performing experiments to measure the ability to discriminate objects visually and to hear a range of sounds (PR–NS2, 3, 4)
 - using a microscope and prepared slides to observe neurons and neuromuscular junctions (PR–NS2, 3, 4)
 - observing the principal features of a mammalian brain, ear and eye, using models, computer simulations or dissections, and identifying the major visible structures of those organs (PR–NS1, 2 3) [ICT F1–4.2]
 - *investigating and integrating, from library and electronic sources, information on the impact of photoperiod and wavelength on humans (PR–NS1, 4) [ICT C1–4.1]*
 - *compiling and displaying, in appropriate format, data collected for investigations on auditory range, reflex arcs and/or stimulus strength versus force of muscle contraction (PR–NS4) [ICT P2–4.1].*

Analyzing and Interpreting

- 30–A1.3s *Students will:*
analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- *interpreting patterns and trends in data on strength of stimuli versus force of muscle contraction (AI–NS2)*
 - *providing a statement that explains the blind spot (AI–NS6)*
 - *explaining how data supports or refutes a hypothesis or prediction on strength of stimulus versus force of muscle contraction (AI–NS6)*
 - *analyzing a hearing aid as a device that simulates a sensory function (PR–ST1) (AI–ST1)*
 - *posing new questions, e.g., why some people are more tolerant to pain than others (AI–NS5)*
 - *collecting and analyzing class data on colour charts (PR–NS4) (AI–NS2) [ICT C7–4.1]*
 - *analyzing data to show the interrelationship between taste and smell receptors (AI–NS2) [ICT C7–4.1].*

Communication and Teamwork

- 30–A1.4s *Students will:*
work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively with group members to investigate neurological disorders such as Alzheimer's disease and Parkinson's disease (CT–NS1, 3) [ICT C1–4.1, 4.2].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Outcomes for Knowledge

Students will:

- 30–A2.1k identify the principal endocrine glands of the human organism, i.e., the hypothalamus/pituitary complex, thyroid and adrenal glands, islet cells of the pancreas
- 30–A2.2k describe the hormones of the principal endocrine glands, i.e., thyroid-stimulating hormone (TSH)/thyroxine, adrenocorticotrophic hormone (ACTH)/cortisol, glucagon/insulin, human growth hormone (hGH), antidiuretic hormone (ADH), epinephrine, norepinephrine, aldosterone
- 30–A2.3k explain the metabolic roles hormones may play in homeostasis, i.e., thyroxine in metabolism, insulin, glucagon, and cortisol in blood sugar regulation, hGH in growth, ADH in water regulation, aldosterone in sodium ion regulation
- 30–A2.4k explain how the endocrine system allows human organisms to sense their internal environment and respond appropriately, e.g., *calcium metabolism, osmotic pressure of blood*
- 30–A2.5k compare the endocrine and nervous control systems and explain how they act together, i.e., stress and the adrenal gland
- 30–A2.6k describe, using an example, the physiological consequences of hormone imbalances, i.e., diabetes mellitus, and e.g., *gigantism, goiter, cretinism, Graves' disease, diabetes insipidus*.

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 30–A2.1sts explain that science and technology are developed to meet societal needs and expand human capability by (STS1)
 - *comparing the function of technological control systems with electrochemical control systems in organisms, e.g., computer control systems for car emissions*
 - *assessing the impact of research into biochemical control systems on human performance*
 - *describing the current treatment technology for type 1 diabetes*
- 30–A2.2sts explain that science and technology have both intended and unintended consequences for humans and the environment by (STS3)
 - *explaining the relationship among ultraviolet light, ozone depletion and pigment deposition within skin cells*
 - *evaluating the use of biotechnology to solve practical problems, e.g., hormone synthesis for diabetes, dwarfism, milk yield in cows*
 - *evaluating the use of hormone therapy in the treatment of humans, e.g., growth hormone and aging, steroids and human performance.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will explain how the endocrine system contributes to homeostasis.*

Skill Outcomes (Focus on decision making)

Initiating and Planning

- Students will:*
- 30–A2.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- formulating a hypothesis, from published data, on an environmental factor that can be detected and responded to by humans, e.g., *ultraviolet light and pigment deposition, diet and thyroid function (IP–NS3) [ICT C6–4.1].*

Performing and Recording

- Students will:*
- 30–A2.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- *researching Seasonal Affective Disorder (SAD) or General Adaptation Syndrome and identifying the main hormonal and nervous components (PR–NS1, 4) [ICT C1–4.1, 4.2].*

Analyzing and Interpreting

- Students will:*
- 30–A2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- inferring the role of ADH and aldosterone in the maintenance of water and ions using the analysis and interpretation of data on blood and urine composition (AI–NS4, 5, 6) [ICT C7–4.2]
 - inferring the role of insulin in the regulation of blood sugar by performing an experiment to investigate the presence of reducing sugars in simulated urine and comparing the results with normal urinalysis data; and/or investigating the role of insulin in the regulation of blood sugar using a computer simulation (AI–NS4, 5, 6) [ICT C7–4.1, 4.2].

Communication and Teamwork

- Students will:*
- 30–A2.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *evaluating individual and group processes used in planning and carrying out group investigations of hormone therapy or use of biotechnology to solve practical problems (CT–NS 1, 3) [ICT C3–4.2].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit B: Reproduction and Development

Themes: Change and Systems

Overview: This unit investigates the human reproductive system as a representative mammalian system responsible for propagating the organism and perpetuating the species. The processes associated with human reproduction and development are reviewed, as well as the regulation of these processes by hormones. The influence of environmental factors on embryonic and fetal development is examined, as well as various reproductive technologies. A brief assessment is made of the variety of reproductive strategies found in nature.

This unit builds on:

- Science 8, Unit B: Cells and Systems
- Science 9, Unit A: Biological Diversity
- Science 10, Unit C: Flow of Matter in Living Systems
- Biology 20, Unit D: Human Systems

This unit will require approximately 20% of the time allotted for Biology 30.

Links to Mathematics: None

Focusing Questions: How do the reproductive systems function to ensure survival of the species? What mechanisms are responsible for regulating the reproductive systems? What are the major processes and events of human embryonic and fetal development? How have reproductive technologies impacted the functioning of the reproductive systems?

General Outcomes: There are three major outcomes in this unit.

Students will:

1. explain how survival of the human species is ensured through reproduction
2. explain how human reproduction is regulated by chemical control systems
3. explain how cell differentiation and development in the human organism are regulated by a combination of genetic, endocrine and environmental factors.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- male and female reproductive systems
- reproductive hormones
- reproductive technologies
- embryonic and fetal development
- parturition
- lactation

General Outcome 1: *Students will* explain how survival of the human species is ensured through reproduction.

Outcomes for Knowledge

Students will:

- 30–B1.1k identify the structures in the female reproductive system and describe their functions, i.e., ovaries, fallopian tubes, uterus, cervix, vagina
- 30–B1.2k identify the structures in the male reproductive system and describe their functions, i.e., testes, seminiferous tubules, interstitial cells, Sertoli cells, epididymides, vasa (ductus) deferentia, Cowper's glands, seminal vesicles, prostate gland, ejaculatory duct, urethra, penis
- 30–B1.3k distinguish egg and sperm from their supporting structures, i.e., seminiferous tubules, interstitial cells, Sertoli cells, follicle, corpus luteum
- 30–B1.4k describe the hormonal and chromosomal factors in the formation of the gonads and reproductive organs in the female and male embryo and fetus, i.e., role of testosterone and Y chromosome
- 30–B1.5k explain how sexually transmitted diseases can interfere with the passage of eggs and sperm, e.g., *chlamydia, gonorrhea, human papilloma virus.*

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 30–B1.1sts explain that decisions regarding the use of scientific and technological developments involve a variety of perspectives, including social, cultural, environmental, ethical and economic considerations by (STS4b)
 - *evaluating the implications of reproductive technology for human biology*
 - *discussing society's expectations of the scientific community with respect to reproductive technology*
 - *discussing the impact of sexually transmitted diseases on an individual, considering the physiological damage they cause.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: *Students will* explain how survival of the human species is ensured through reproduction.

Skill Outcomes (Focus on decision making)

Initiating and Planning

- Students will:*
- 30–B1.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- *identifying ethical concerns about, e.g., (IP–STS1, 2, 3) [ICT C7–4.1]*
 - *reproductive technologies*
 - *infertility*
 - *spread of STDs.*

Performing and Recording

- Students will:*
- 30–B1.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- observing the principal features of the human reproductive system using models or computer simulations, and identifying the major structures from drawings (PR–NS1, 4) [ICT F1–4.2]
 - using a microscope to observe prepared slides of ovaries and testes so as to distinguish eggs and sperm from their supporting structures, i.e., follicle, corpus luteum, seminiferous tubules, interstitial cells, Sertoli cells (PR–NS3, 4).

Analyzing and Interpreting

- Students will:*
- 30–B1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- evaluating practical solutions to decreased fertility, i.e., low sperm count, difficulty in egg production, hormonal imbalance by (AI–ST2) (AI–STS2)
 - *evaluating information collected from library and electronic sources on the implications of reproductive technologies, e.g., surrogate mothers, sperm banks, cloning (AI–STS2, 4) [ICT C1–4.1, C3–4.1, 4.2].*

Communication and Teamwork

- Students will:*
- 30–B1.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- working cooperatively as a team to research the physiological and physical damage to reproductive organs caused by exposure to sexually transmitted disease organisms and, using appropriate multimedia, present the findings to the class (CT–STS1, 2, 4) [ICT P6–4.1, C1–4.4].

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will* explain how human reproduction is regulated by chemical control systems.

Outcomes for Knowledge

Students will:

- 30–B2.1k describe the role of hormones in the regulation of primary and secondary sex characteristics in females and males
- 30–B2.2k identify the principal reproductive hormones in the female and explain their interactions in the maintenance of the menstrual cycle, i.e., estrogen, progesterone, luteinizing hormone (LH), follicle-stimulating hormone (FSH)
- 30–B2.3k identify the principal reproductive hormones in the male and explain their interactions in the maintenance and functioning of the male reproductive system, i.e., testosterone, luteinizing hormone (LH), follicle-stimulating hormone (FSH)
- 30–B2.4k compare the cyclical patterns of reproduction in non-primate mammals with that of humans, i.e., estrus cycle versus the menstrual cycle.

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 30–B2.1sts explain how science and technology are influenced and supported by society and have influenced, and been influenced by, historical development and societal needs by (STS2)
 - *researching and assessing the effects of the medical use of reproductive hormones on humans*
 - *researching and assessing the implications for humans of producing and using reproductive hormones in domestic animals, e.g., cattle and horses*
- 30–B2.2sts explain why decisions regarding the use of scientific and technological developments involve a variety of perspectives, including social, cultural, environmental, ethical and economic considerations by (STS4b)
 - *explaining how reproductive hormone homeostasis is disrupted by the natural aging process and whether available technologies should be used to restore balance; e.g., hormone treatment for menopause and andropause.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will explain how human reproduction is regulated by chemical control systems.*

Skill Outcomes (Focus on decision making)

Initiating and Planning

- Students will:*
- 30–B2.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues, e.g., by
- *designing an investigation to determine at which point during the menstrual cycle a female is most fertile (IP–NS2, 3, 4) [ICT C7–4.1].*

Performing and Recording

- Students will:*
- 30–B2.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- graphing the changes in estrogen, progesterone, LH and FSH levels in the blood of a female through a single menstrual cycle (PR–NS4) [ICT P2–4.1, C6–4.2, 4.3]
 - using models, diagrams or computer simulations, identifying the follicle and corpus luteum within the ovary (PR–NS1, 4) [ICT C7–4.1].

Analyzing and Interpreting

- Students will:*
- 30–B2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- analyzing blood hormone data and physiological events for a single menstrual cycle, inferring the roles of female sex hormones (AI–NS2, 6) [ICT C6–4.4]
 - analyzing blood hormone data and physiological events, inferring the roles of male sex hormones (AI–NS2, 6) [ICT C6–4.4]
 - *researching and assessing the effects of the medical use of reproductive hormones, e.g., menopause, andropause, infertility (PR–STS1) (AI–STS2, 3, 4) [ICT C2–4.1].*

Communication and Teamwork

- Students will:*
- 30–B2.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- selecting and using appropriate numerical and graphical modes of representation to communicate information on changing reproductive hormone levels in the blood (CT–ST2) [ICT C6–4.3]
 - *working cooperatively with team members to investigate the value of producing and using reproductive hormones in domestic animals and, using the appropriate multimedia, present the information to the class (CT–STS1, 2, 3, 4) [ICT C7–4.1, 4.3, P6–4.1, P4–4.1].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3: *Students will explain how cell differentiation and development in the human organism are regulated by a combination of genetic, endocrine and environmental factors.*

Outcomes for Knowledge

Students will:

- 30–B3.1k trace the processes of fertilization, implantation, and extra-embryonic membrane formation; i.e., amnion, chorion, followed by embryo development, placental and fetal development, parturition and lactation, and the control mechanisms of the above events, i.e., progesterone, LH, human chorionic gonadotropin (hCG), oxytocin, prolactin, prostaglandins
- 30–B3.2k describe development from fertilization to parturition in the context of the main physiological events that occur in the development of organ systems during each major stage (trimester), i.e., zygote, blastocyst, gastrulation, general morphogenesis
- 30–B3.3k identify major tissues and organs that arise from morphological development of the ectoderm, mesoderm and endoderm in the embryo, i.e.,
 - ectoderm: nervous system, epidermis
 - mesoderm: skeleton, muscles, reproductive structures
 - endoderm: lining of the digestive and respiratory systems, endocrine glands
- 30–B3.4k describe the influence of environmental factors on embryonic and fetal development of body structures or systems, e.g., *maternal lifestyle, teratogens such as alcohol, drugs, viral infections*
- 30–B3.5k describe the physiological or mechanical basis of different reproductive technology methods, i.e., conception control, *in vitro* fertilization, infertility reversal.

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 30–B3.1sts explain that science and technology are developed to meet societal needs and expand human capability by (STS1)
 - *analyzing the use of technology to solve problems of immunological incompatibility between fetus and mother and possible solutions to such problems*
- 30–B3.2sts explain why decisions regarding the application of scientific and technological development involve a variety of perspectives including social, cultural, environmental, ethical and economic considerations by (STS4b)
 - *assessing the effects of conception control technology on population demographics in developed and underdeveloped countries*
 - *assessing the use of imaging technologies in monitoring fetal development, e.g., ultrasound*
 - *discussing how knowledge of embryonic/fetal development has influenced the value that society places on human life*
 - *discussing the societal impact of chemicals on fetal development, e.g., environmental contaminants such as polychlorinated biphenyls (PCBs), heavy metals, dioxins and furans.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3: *Students will explain how cell differentiation and development in the human organism are regulated by a combination of genetic, endocrine and environmental factors.*

Skill Outcomes (Focus on decision making)

Initiating and Planning

- Students will:*
- 30–B3.1s ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues by
- *designing an experiment to test for pregnancy (IP–NS2, 3, 4) [ICT C7–4.1].*

Performing and Recording

- Students will:*
- 30–B3.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- *investigating, using library and electronic sources, the effects of environmental factors on human embryonic and fetal development, e.g., alcohol, cocaine, cigarette smoke, diet and prescription drugs (PR–NS1) (PR–STS1, 2) [ICT C2–4.1, 4.2]*
 - *investigating, using library and electronic sources, how embryonic cells communicate during development*
 - *researching the societal impact of technology, e.g., ultrasound, amniocentesis, in vitro fertilization, chorionic villi sampling.*

Analyzing and Interpreting

- Students will:*
- 30–B3.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- *observing the changes during embryo development, using preserved material such as chicken embryos, prepared slides, models or computer simulations, and extrapolating these events to the development of a human (PR–NS2, 3) (AI–NS2) [ICT F1–4.2]*
 - *evaluating, from published data, the effectiveness and safety of various reproductive technologies (AI–STS1, 2, 3, 4) [ICT C2–4.1]*
 - *interpreting hormonal data from published investigations, e.g., pregnancy testing (AI–NS2) [ICT C7–4.2]*
 - *analyzing the stages of embryo development (AI–NS2) [ICT C7–4.2].*

Communication and Teamwork

- Students will:*
- 30–B3.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *developing clear and logical arguments, based on published data, to defend a given decision on the effectiveness and safety of available reproductive technologies (CT–STS3) [ICT C1–4.4].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit C: Cell Division, Genetics and Molecular Biology

Themes: Change and Diversity

Unit Overview: This unit examines the two types of cell division, mitosis and meiosis. With an understanding of chromosomal behaviour during cell division, students expand their knowledge of chromosomes by studying classical genetics. Classical genetics is further extended to a molecular level by exploring the basic structure of deoxyribonucleic acid (DNA), its role in protein synthesis and the impact of mutation.

This unit builds on:

- Science 9, Unit A: Biological Diversity

This unit will require approximately 40% of the time allotted for Biology 30.

Links to Mathematics:

The following mathematics topics are not considered as prerequisites.

Topics:

- expressing experimental results with appropriate recognition of experimental error
- modelling the probability of a compound event, and solve problems based on the combining of simpler probabilities

This topic may be found in the following courses:

Applied Mathematics 20, specific outcomes 6.2, 6.3 and 6.4

Applied Mathematics 30, specific outcomes 2.4, 2.5, 2.6 and 2.7

Focusing Questions: What cellular processes allow for reproduction, and growth of an organism? What regulates the transmission of genetic information from one generation to the next? How is DNA responsible for the production of proteins?

General Outcomes: There are three major outcomes in this unit.

Students will:

1. describe the processes of mitosis and meiosis
2. explain the basic rules and processes associated with the transmission of genetic characteristics
3. explain classical genetics at the molecular level.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- cell cycle
- mitosis and meiosis
- chromosome number
- karyotype
- alternation of generations
- Mendel's laws of heredity
- probability
- monohybrid, dihybrid and sex-linked inheritance
- incomplete dominance and codominance
- polygenic and multiple allelic traits
- gene linkage and chromosome mapping
- Watson and Crick model of DNA
- replication
- transcription
- translation
- mutation
- genetic engineering

General Outcome 1: *Students will describe the processes of mitosis and meiosis.*

Outcomes for Knowledge

Students will:

- 30–C1.1k define and explain the significance of chromosome number in somatic and sex cells; i.e., haploidy, diploidy and polyploidy
- 30–C1.2k explain, in general terms, the events of the cell cycle, i.e., interphase, chromosomal behaviour in mitosis and cytokinesis
- 30–C1.3k describe the processes of spermatogenesis and oogenesis and the reduction of chromosomal number in meiosis
- 30–C1.4k compare the processes of mitosis and meiosis
- 30–C1.5k describe the processes of nondisjunction and crossing over and evaluate their significance to organism inheritance and development
- 30–C1.6k compare the formation of fraternal and identical offspring in a single birthing event
- 30–C1.7k describe the diversity of reproductive strategies by comparing the alternation of generations in a range of organisms; e.g., *protists, Daphnia, sea anemone, moss, pine.*

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 30–C1.1sts explain that science and technology are developed to meet societal needs and expand human capability by (STS1)
 - *discussing the role of mitosis and biotechnology in regenerating damaged or missing parts of organisms, e.g., stem cells*
 - *evaluating how a knowledge of cell division or development of nanotechnology might be applied to the regulation of cancerous growth in plants or animals*
 - *discussing and assessing the impact of research in plant and animal reproduction on our understanding of mitosis and meiosis in humans, e.g., cloning, chromosome shortening*
 - *discussing the types and sources of teratogenic compounds found in the environment and the technological means by which they can be removed or controlled to ensure quality of life for future generations.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: *Students will describe the processes of mitosis and meiosis.*

Skill Outcomes (Focus on problem solving)

Initiating and Planning

- Students will:*
- 30–C1.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- *defining questions related to mitosis and meiosis, e.g., chromosome shortening, conditions/stimuli for meiosis, aging and mitosis, cytokinesis (IP–NS1) [ICT C7–4.1].*

Performing and Recording

- Students will:*
- 30–C1.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- performing a simulation to demonstrate the behavior of chromosomes during mitosis (PR–NS2) [ICT C6–4.4]
 - using a microscope and prepared slides of onion root tip cells to identify the stages of a cell cycle and calculate the duration of each stage (PR–NS 2, 4)
 - researching a range of reproductive strategies in organisms and presenting them in the form of charts, tables or diagrams, e.g., *alternation of generation showing sexual and asexual phases such as budding, spore production, binary fission (PR–NS1) [ICT C1–4.1, C6–4.3]*
 - *preparing microscope slides to demonstrate some stages of mitosis and meiosis (PR–NS2, 3, 4).*

Analyzing and Interpreting

- Students will:*
- 30–C1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- preparing and interpreting models of human karyotypes (PR–NS1) (AI–NS2) [ICT C6–4.4]
 - *analyzing the similarities and differences of cell division in plants and animals (AI–NS2, 6).*

Communication and Teamwork

- Students will:*
- 30–C1.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively with team members in the preparation of mitosis slides (CT–NS1)*
 - *presenting two contrasting reproductive strategies, emphasizing the differences (CT–NS2) [ICT P6–4.1].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will explain the basic rules and processes associated with the transmission of genetic characteristics.*

Outcomes for Knowledge

Students will:

- 30–C2.1k describe the evidence for segregation and the independent assortment of genes on different chromosomes, as investigated by Mendel
- 30–C2.2k compare ratios and probabilities of genotypes and phenotypes for dominant/recessive alleles, multiple alleles and incompletely dominant or codominant alleles
- 30–C2.3k explain the limitations of variability due to gene linkage and the influence of crossing over on assortment of genes on the same chromosome
- 30–C2.4k explain the relationship between variability and the number of genes controlling a trait, e.g., *one pair of genes, as for Rh factor, versus two or more pairs of genes, as for skin colour, height*
- 30–C2.5k compare the pattern of inheritance produced by genes on the sex chromosomes to that of genes on autosomes, as investigated by Morgan and others.

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 30–C2.1sts explain that decisions regarding the application of scientific and technological development involve a variety of perspectives including social, cultural, environmental, ethical and economic considerations by (STS4b)
 - *evaluating the needs and interests of society and the role of genetic counselling and technology in the identification and treatment of potentially disabling genetic disorders, e.g., phenylketonuria, cystic fibrosis, germ-cell modification*
 - *discussing the application of genetic crosses in the development of specific breeds or hybrids, e.g., wheat, corn.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will explain the basic rules and processes associated with the transmission of genetic characteristics.*

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- Students will:*
- 30–C2.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- designing a plan for collecting data to demonstrate human inheritance (IP–NS1, 2, 4) [ICT C7–4.1].

Performing and Recording

- Students will:*
- 30–C2.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- performing an experiment to demonstrate inheritance of a trait controlled by a single pair of genes, e.g., *albino corn*, *Brassica (Wisconsin fast plant)*, *Drosophila* or *Arabidopsis* (PR–NS2, 3, 4)
 - designing and performing an experiment to demonstrate that an environmental factor can cause a change in the expression of genetic information in an organism (IP–NS1, 2, 3, 4) (PR–NS1, 2, 3, 4, 5).

Analyzing and Interpreting

- Students will:*
- 30–C2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- interpreting patterns and trends in data by predicting, quantitatively, the probability of inheritance from monohybrid, dihybrid and sex-linked inheritance (AI–NS2)
 - using Punnett squares, interpret patterns and trends in data associated with monohybrid, dihybrid and sex-linked patterns of inheritance (AI–NS2)
 - performing, recording and explaining predicted phenotypic ratios versus actual counts in genetic crosses to show a relationship between chance and genetic results (PR–NS2, 3, 4) (AI–NS3)
 - drawing and interpreting pedigree charts from data on human single-allele and multiple-allele inheritance patterns, e.g., *hemophilia*, *blood types* (PR–NS4) (AI–NS2) [ICT C7–4.2]
 - analyzing crossover data for a single pair of chromosomes to create a chromosome map showing gene arrangement and relative distance (AI–NS2)
 - *providing a concluding statement on assortment of linked genes (AI–NS6)*
 - *identifying limitations of data associated with phenotypic ratios for small populations in which the ratios may not conform with the theoretical ratios expected (AI–NS4).*

Communication and Teamwork

- Students will:*
- 30–C2.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively with team members to investigate a monohybrid cross, e.g., tongue rolling, attached ear lobes and solve problems as they arise (CT–NS1, 2).*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3: *Students will explain classical genetics at the molecular level.*

Outcomes for Knowledge

Students will:

- 30–C3.1k summarize the historical events that led to the discovery of the structure of the DNA molecule, as described by Watson and Crick
- 30–C3.2k describe, in general, how genetic information is contained in the sequence of bases in DNA molecules in chromosomes; how the DNA molecules replicate themselves; and how the genetic information is transcribed into sequences of bases in RNA molecules and is finally translated into sequences of amino acids in proteins
- 30–C3.3k explain, in general, how restriction enzymes cut DNA molecules into smaller fragments and how ligases reassemble them
- 30–C3.4k explain, in general, how cells may be transformed by inserting new DNA sequences into their genomes
- 30–C3.5k explain how a random change (mutation) in the sequence of bases provides a source of genetic variability
- 30–C3.6k explain how information in nucleic acids contained in the nucleus, mitochondria and chloroplasts gives evidence for the relationships among organisms of different species.

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 30–C3.1sts explain that science and technology have both intended and unintended consequences for humans and the environment by (STS3)
 - *discussing the implications for society of corporations being able to patent genes, e.g., gene for Roundup resistance in canola*
 - *assessing the concerns and benefits of genetically modified organisms, e.g., transgenic food organisms, tree cloning for reforestation*
- 30–C3.2sts explain that scientific research and technological development help achieve a sustainable society, economy and environment by (STS4a)
 - *discussing the Human Genome Project and the potential of proteomic technologies, in terms of the needs, interests and financial support of society*
 - *discussing biotechnology and gene replacement therapy in the treatment of human genetic disorders*
 - *assessing the impact and value of DNA sequencing on the study of genetic relationships and variations in population ecology*
 - *exploring the application of nanotechnology and its implications for clinical diagnostics, pharmacology, biological research or proteomic programs.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3: *Students will explain classical genetics at the molecular level.*

Skill Outcomes (Focus on problem solving)

Initiating and Planning

- Students will:*
- 30–C3.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues, e.g., by
- *designing an experiment to identify the proteins produced in a cell at a particular point in time or development, e.g., microarrays (IP–NS1, 2, 3, 4) [ICT C7–4.1].*

Performing and Recording

- Students will:*
- 30–C3.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- constructing models of DNA to demonstrate the general structure and base arrangement (PR–NS2, 4) [ICT C7–4.2, C6–4.4]
 - performing simulations to demonstrate the replication of DNA and the transcription and translation of its information (PR–NS2, 4) [ICT C7–4.2, C6–4.4]
 - performing simulations to demonstrate the use of restriction enzymes and ligases (PR–NS2, 4)
 - *performing an investigation to extract DNA from cells, e.g., green peas or beans, bananas or onions (IP–NS2, 4) (PR–NS1, 2, 3, 4, 5)*
 - *researching gel electrophoresis techniques and their applications in medical diagnostics and forensics (PR–ST1) [ICT C1–4.2].*

Analyzing and Interpreting

- Students will:*
- 30–C3.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- analyzing relationships, from published data, between human activities and changes in genetic information that lead to heritable mutations and cancer (AI–NS2) [ICT C1–4.2, C7–4.2]
 - *analyzing DNA fingerprints (AI–NS2).*

Communication and Teamwork

- Students will:*
- 30–C3.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *working cooperatively with team members to investigate the impact of an environmental factor on the expression of a gene and solving problems as they arise (CT–NS1) [ICT C7–4.1].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit D: Population and Community Dynamics

Themes: Systems, Equilibrium and Change

Unit Overview: Population change over time can be examined through a study of population genetics (Hardy–Weinberg Principle) and population growth. Both of these can be expressed quantitatively. Individual members of populations interact with each other as well as with members of other populations, which can have an impact on the populations involved. Communities are a sum of all the different populations living together. Communities may change over time as a result of natural or artificial events.

This unit builds on:

- Science 9, Unit A: Biological Diversity
- Biology 20, Unit B: Ecosystems and Population Change

This unit will require approximately 15% of the time allotted for Biology 30.

Links to Mathematics:

The following mathematics topics are not considered as prerequisites.

Topics:

- interpret nonlinear data
- solving nonlinear equations using graphical or algebraic methods with appropriate technology
- expressing experimental results with appropriate recognition of experimental error

These topics may be found in the following courses:

Pure Mathematics, specific outcome 3.1; Applied Mathematics, specific outcome 3.1

Pure Mathematics 10, specific outcome 4.2, and Pure Mathematics 20, specific outcomes 2.1, 2.3, 2.4, and 3.1; Applied Mathematics 10, specific outcomes 3.2, 3.3 and 5.1, and Applied Mathematics 20, specific outcomes 2.1, 2.3, 2.4 and 2.5

Applied Mathematics 20, specific outcomes 6.2, 6.3 and 6.4

Focusing Questions: How does one determine if populations are changing over time? In what ways may individual members of a population interact with each other or with members of a different population? What quantitative measures indicate that populations change over time?

General Outcomes: There are three major outcomes in this unit.

Students will:

1. describe a community as a composite of populations in which individuals contribute to a gene pool that can change over time
2. explain the interaction of individuals in populations with each other and with members of other populations
3. explain, in quantitative terms, the changes in populations over time.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- Hardy–Weinberg Principle
- gene pool
- natural selection
- symbiotic relationships and other interactions
- succession
- determiners of population size: natality, mortality, immigration, emigration
- population growth rate and population growth curves
- *r*- and *K*-selected reproductive strategies

General Outcome 1: *Students will describe a community as a composite of populations in which individuals contribute to a gene pool that can change over time.*

Outcomes for Knowledge

Students will:

- 30–D1.1k describe the Hardy–Weinberg Principle and explain its importance to population gene-pool stability and the significance of non-equilibrium values
- 30–D1.2k describe the factors that cause the gene pool diversity to change, i.e., genetic drift, gene flow, non-random mating, bottleneck effect, migration, mutation
- 30–D1.3k apply quantitatively, the Hardy–Weinberg Principle to observed and published data
 - $p + q = 1$
 - $p^2 + 2pq + q^2 = 1$
- 30–D1.4k describe the molecular basis of gene-pool change and the significance of these changes over time, i.e., mutations and natural selection, e.g., *drug-resistant bacteria, herbicide-resistant plants.*

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 30–D1.1sts explain that science and technology have both intended and unintended consequences for humans and the environment by (STS3)
 - *discussing the introduction of exotic species into new ecosystems*
 - *discussing the development of ecological reserves to preserve gene-pool diversity*
 - *assessing the bottleneck effect characteristic of small populations and strategies to counteract it, e.g., Whooping crane, Swift fox*
 - *investigating the role of gene banks in the preservation of endangered species and genotypes, particularly of plants and animals used in agriculture*
 - *assessing habitat loss and the responsibility of society to protect the environment for future generations*
- 30–D1.2sts explain how concepts, models and theories are often used in interpreting and explaining phenomena by (NS6a)
 - *assessing the role and importance of models in ecology in explaining scientific phenomena, e.g., Hardy–Weinberg Principle.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: *Students will* describe a community as a composite of populations in which individuals contribute to a gene pool that can change over time.

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

- Students will:*
- 30–D1.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- *identifying a question about the resistance of bacteria to specific antibiotics or plants to specific herbicides (IP–NS1) [ICT C7–4.1].*

Performing and Recording

- Students will:*
- 30–D1.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- designing and performing an investigation and/or computer simulation to demonstrate population growth and gene-pool change (IP–NS1, 2, 3, 4) (PR–NS1, 2, 3, 4, 5) [ICT C7–4.1, C1–4.1]
 - *researching, integrating and synthesizing information on a related topic, e.g., (PR–NS1) [ICT C1–4.1, C7–4.2]*
 - *the development and persistence of deleterious genes in gene pools*
 - *development of bacterial resistance to antibiotics.*

Analyzing and Interpreting

- Students will:*
- 30–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- calculating and interpreting problem-solving exercises involving the Hardy–Weinberg Principle (AI–NS6) [ICT C6–4.4].

Communication and Teamwork

- Students will:*
- 30–D1.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *using appropriate notation to show gene frequency and changes in gene frequency over time (CT–NS1).*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will* explain the interaction of individuals in populations with each other and members of other populations.

Outcomes for Knowledge

Students will:

- 30–D2.1k describe the basis of species interactions and symbiotic relationships and their influences on population changes, i.e.,
- predator-prey and producer-consumer relationships
 - symbiotic relationships: commensalism, mutualism and parasitism
 - interspecific and intraspecific competition
- 30–D2.2k explain the role of defense mechanisms in predation and competition, e.g., *mimicry, protective coloration, toxins, behaviour*
- 30–D2.3k explain how mixtures of populations that define communities may change over time or remain as a climax community, i.e., primary succession, secondary succession.

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

- 30–D2.1sts explain why Canadian society supports scientific research and technological development that helps achieve a sustainable society, economy and environment by (STS4a)
- *discussing public support of scientific work done on predator-prey relationships as part of wildlife management in national and provincial parks, e.g., introduction of wolves*
 - *assessing the long-term implications of fire control and prevention on population and ecosystem stability, diversity and productivity*
 - *assessing the impact of parasites on humans and how this impact could be reduced.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: *Students will explain the interaction of individuals in populations with each other and members of other populations.*

Skill Outcomes

Initiating and Planning

Students will:

- 30–D2.1s ask questions about observed relationships, and plan investigations of questions, ideas, problems and issues by
- *planning an investigation of species interaction in a national park or wilderness area (IP–NS1, 2, 3) [ICT C7–4.1].*

Performing and Recording

Students will:

- 30–D2.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- designing and performing an experiment or simulation to demonstrate interspecific and intraspecific competition (IP–NS1, 2, 3, 4) (PR–NS1, 2, 3, 4, 5) [ICT C7–4.1]
 - designing and performing an experiment to demonstrate succession in a microenvironment and record its pattern of succession over time, e.g., *hay infusion* (IP–NS1, 2, 3, 4) [ICT C7–4.1]
 - performing simulations to investigate relationships between predators and their prey, e.g., *computer simulation, role playing* (PR–NS1, 2, 3, 4) [ICT C6–4.4].

Analyzing and Interpreting

Students will:

- 30–D2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- summarizing and evaluating a symbiotic relationship (PR–NS1) (AI–NS6)
 - *researching and analyzing clearcutting versus selective logging practices (PR–STS1, 2, AI–STS1, 2, 3) [ICT C2–4.1].*

Communication and Teamwork

Students will:

- 30–D2.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *researching and presenting practical solutions for reducing the impact of highway fencing on animals in Banff and Jasper National Parks (CT–STS1, 2) [ICT C1–4.1, P3–4.1]*
 - *developing, presenting and defending a position on whether organisms should be deliberately introduced into new environments (CT–STS1, 2) [ICT C7–4.1, 4.2, 4.3]*
 - *researching and presenting characteristics of interrelationships between organisms for analysis by classmates (CT–STS1, 2) [ICT C7–4.1, 4.2, 4.3].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3: *Students will explain, in quantitative terms, the change in populations over time.*

Outcomes for Knowledge

Students will:

- 30–D3.1k describe and explain, quantitatively, factors that influence population growth, i.e.,
- mortality, natality, immigration, emigration
 - change in population size, $\Delta N = [\text{natality } (n) + \text{immigration } (i)] - [\text{mortality } (m) + \text{emigration } (e)]$
- 30–D3.2k describe the growth of populations in terms of the mathematical relationship among carrying capacity, biotic potential, environmental resistance and the number of individuals in the population, i.e.,
- growth rate, $gr = \frac{\Delta N}{\Delta t}$, where ΔN is change in number and Δt is change in time
 - per capita growth rate, $cgr = \frac{\Delta N}{N}$, where ΔN is the change in number over a specified time period, and N is the original number of individuals
 - population density, $D_p = \frac{N}{A}$, or $D_p = \frac{N}{V}$, where N is number of individuals in a given space; i.e., area (A), or volume (V) occupied by a population
- 30–D3.3k explain the different population growth patterns, i.e.,
- logistic growth pattern (S-shaped curve) and exponential growth pattern (J-shaped curve)
 - open and closed populations
- 30–D3.4k describe the characteristics and reproductive strategies of *r*-selected and *K*-selected organisms.

Outcomes for Science, Technology and Society (Emphasis on the nature of science)

Students will:

- 30–D3.1sts explain how concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations by (NS5a, b, c, d, e)
- *developing appropriate investigative strategies for analyzing biological issues, e.g., risk/benefit analysis, cost/benefit analysis*
 - *comparing the growth of the human population with that of populations of other species.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3: *Students will explain, in quantitative terms, the change in populations over time.*

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

Students will:

- 30–D3.1s ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by
- *identifying questions about factors that affect population growth rates (IP–NS1).*

Performing and Recording

Students will:

- 30–D3.2s conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by
- *designing and performing an experiment to demonstrate the effect of environmental factors on population growth rate (IP–NS1, 2, 3, 4) (PR–NS1, 2, 3, 4)*
 - *monitoring a paramecium population over time using a microscope and a grid slide (PR–NS2, 3, 4)*
 - *researching zebra mussel population growth in the Great Lakes (PR–NS1, 4) [ICT C1–4.2]*
 - *researching the impact of introduced trout species on bull trout (Salvelinus confluentus) in Alberta lakes and streams (PR–NS1) [ICT C1–4.2].*

Analyzing and Interpreting

Students will:

- 30–D3.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions by
- *graphing and interpreting population growth of *r*-selected and *K*-selected organisms (AI–NS2) [ICT C6–4.3]*
 - *comparing and assessing human population growth rates in various countries (AI–NS2) [ICT C7–4.2]*
 - *demonstrating and assessing the effect of environmental factors on population growth curves (AI–NS2, 6)*
 - *calculating and interpreting density, population change and per capita growth rate (AI–NS2, 3, 4) [ICT P2–4.1]*
 - *calculating population growth rate under ideal conditions given specific parameters (AI–NS3, 4) [ICT P2–4.1]*
 - *stating, based on data, a generalization for the growth of a closed population (AI–NS2, 6).*

Communication and Teamwork

Students will:

- 30–D3.4s work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by
- *developing, presenting and defending a position on Earth's carrying capacity of Homo sapiens (STS1, 2) [ICT C7–4.1, 4.2, 4.3].*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

